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The MINERvA Experiment

Minerba Betancourt

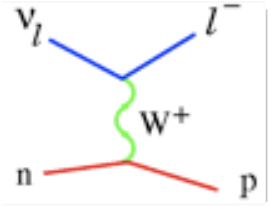
Workshop on the Intermediate Neutrino Program

05 February 2015

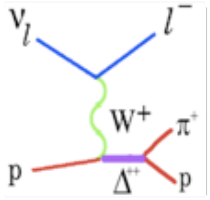
Introduction

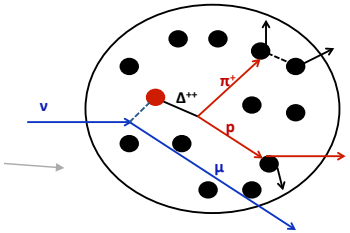
- Charged current processes are signal channels for oscillation experiments
- Due to nuclear effects combined with cross section, the signal channel and neutrino energy measured in detectors are not necessarily the same as the initial interaction

CC Quasi-Elastic



CC Resonance



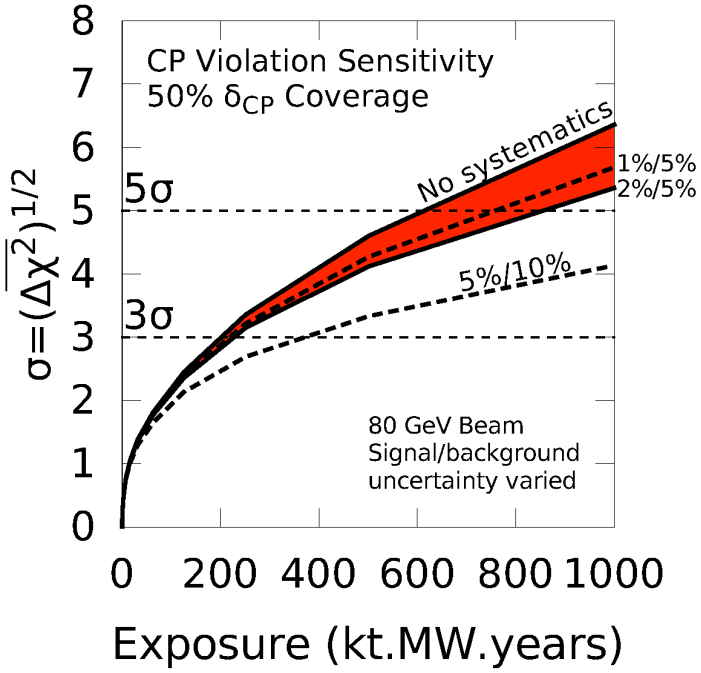


Pion Absorption: Due to final state interactions particles can interact with nucleons before exiting the nucleus

- A pattern of neutrino oscillation is analyzed based on distributions of detected particles and it is crucial to have a reliable MC generator to read this pattern correctly
- Recent experimental data is not well described by current models
- Understanding the neutrino interactions with nuclei is vital for precision oscillation measurements

How different levels of systematic uncertainties impact the CP violation in ELBNF

- CP violation sensitivities as a function of exposure

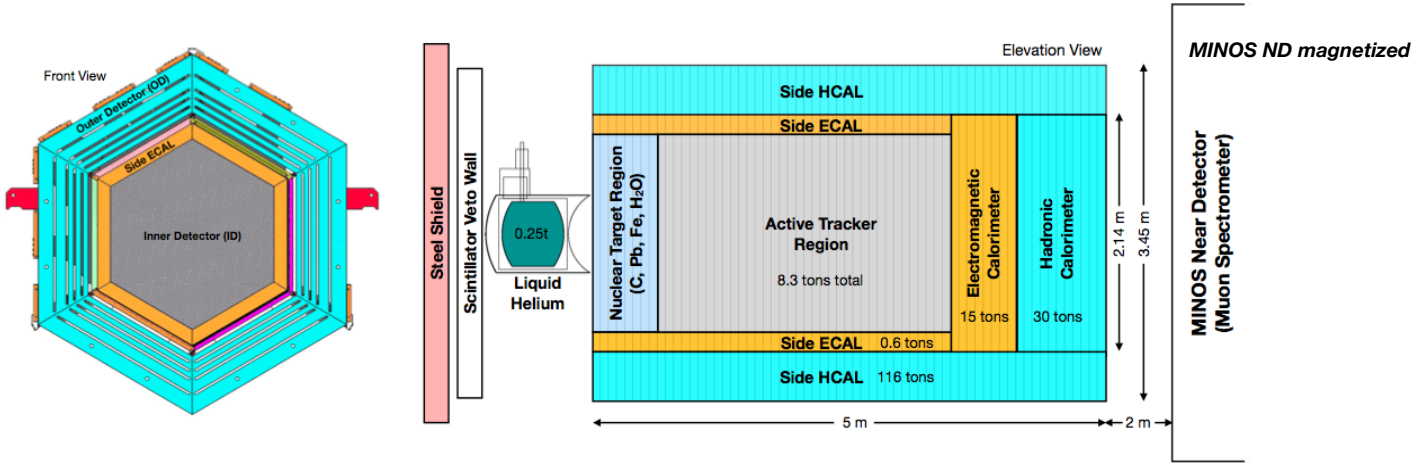


An Experimental Program in Neutrinos, Nucleon Decay and Astroparticle Physics Enabled by the Fermilab Long-Baseline Neutrino Facility

- Oscillation experiments see differences between near detector data and MC generators well above the systematic errors assumed here
- Systematic uncertainties are important for the CP violation measurement

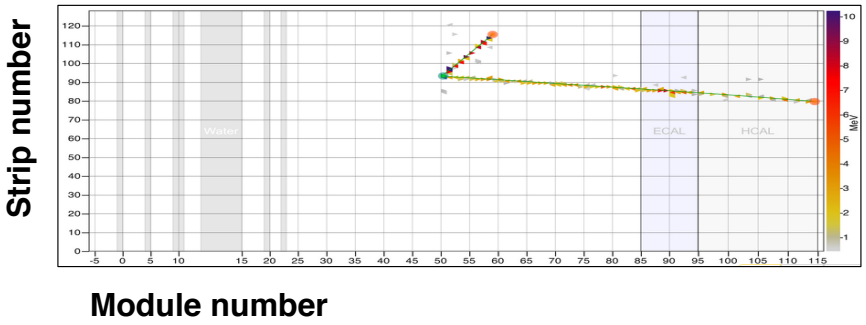
MINERvA Experiment

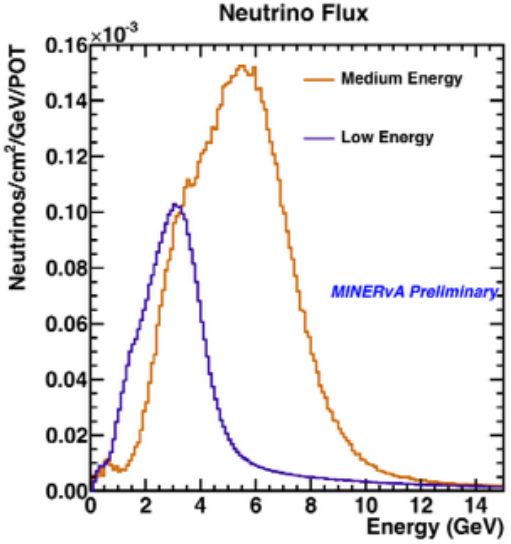
- Fine-grained scintillator surrounded by calorimeters



Running with the medium energy spectrum

Data Event



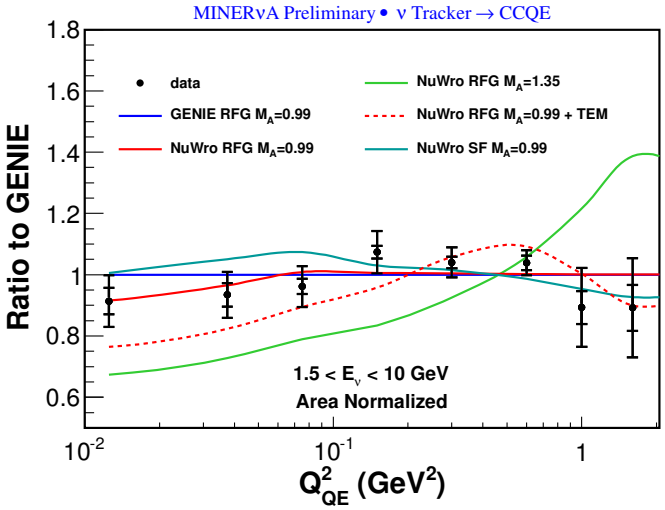


Fermilab

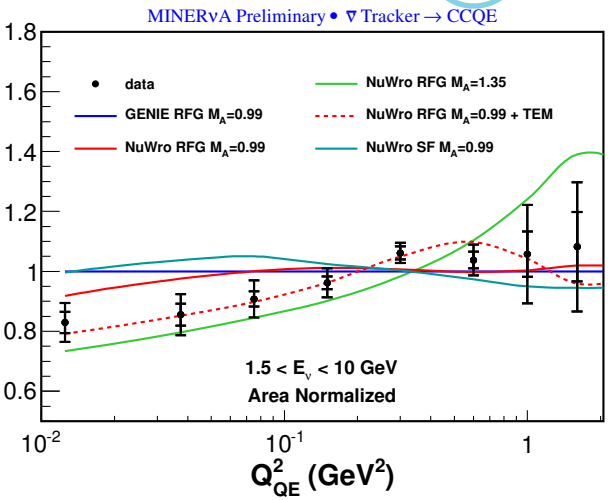
Charged Current Quasi-Elastic Scattering

- MINERvA uses the lepton kinematics and the hadronic part of the interaction to measure the CCQE single differential cross section and discriminates between nuclear models

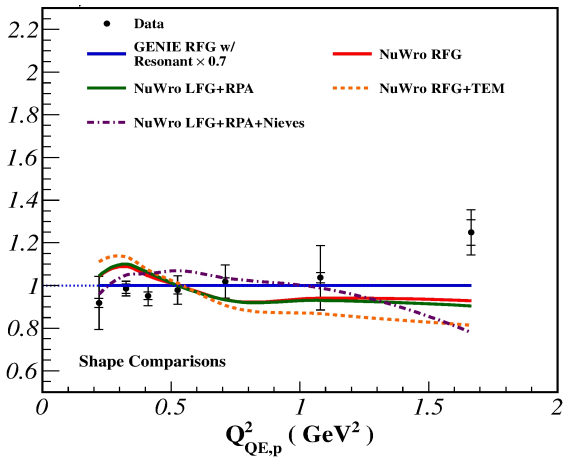
Neutrino $\nu_\mu + n \rightarrow \mu^- + p$ **AntiNeutrino** $\bar{\nu}_\mu + p \rightarrow \mu^+ + n$ **Neutrino** $\nu_\mu + n \rightarrow \mu^- + p$



Phys. Rev. Lett. 111, 022501 (2013)



Phys. Rev. Lett. 111, 022502 (2013)

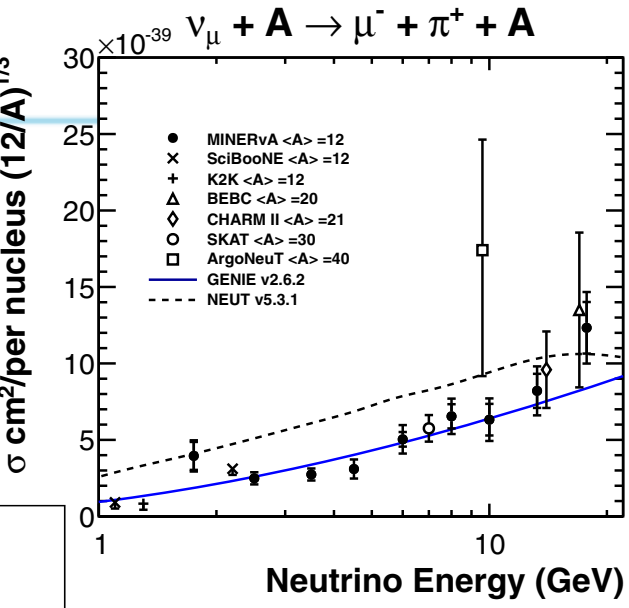


arXiv:1409.4497

- Data prefers a model with nucleon-nucleon correlations, this can be combined with MINIBooNE results to constrain the models and reduce the uncertainties for oscillation measurements
- Underway:
  - Double differential cross section of neutrino and antineutrinos, (results this year)
  - CCQE ratios in nuclear targets using the hadronic part of the interaction
  - CCQE analyses using the medium energy NuMI beam

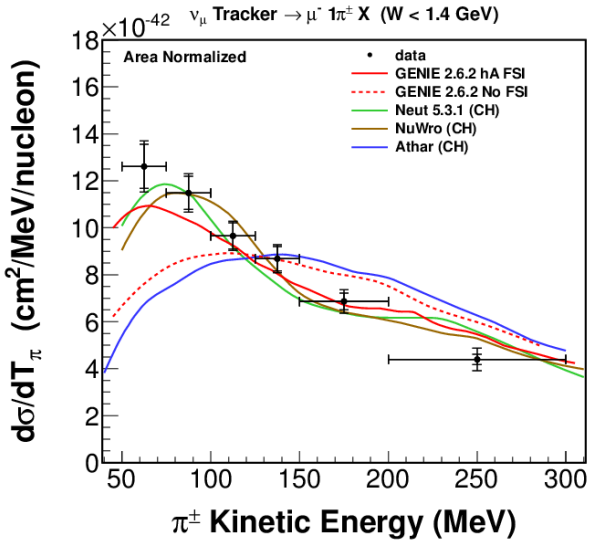
Pion Production

- MINERvA's pion production measurements:
  - Coherent cross section for neutrinos and antineutrinos
  - Differential cross section for neutrino single π^+ production and antineutrino single π^0 production



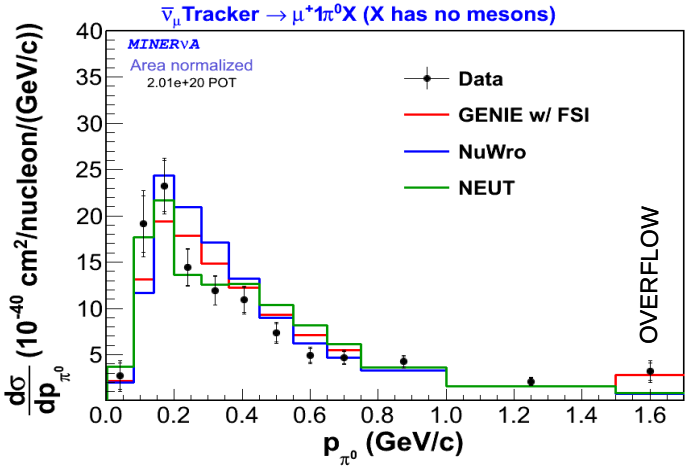
Phys. Rev. Lett. 113, 261802 (2014)

Neutrino CC single π^+ production



arXiv:1406.6415

AntiNeutrino CC single π^0 production

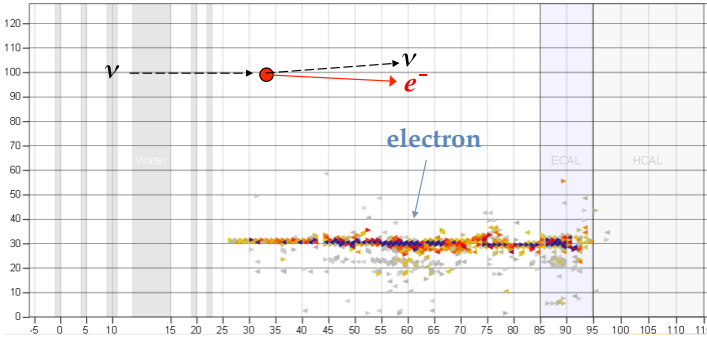


Trung Le/Fermilab Wine and Cheese

- MINERvA pion kinematics show broad agreement with final state simulations in shape and disagreement in absolute measurement
- These are initial measurements for pion production
- More to come with the high statistics from medium energy

Synergies with other Experiments and Event Generators

- MINERvA is open to any request from oscillation experiments
  - Collaboration with T2K experiment, we provide constrains for CCQE
- Neutrino elastic scattering on electron is used to constrain the flux, analysis is now complete in the low energy beam. This method can be used for NOvA and LBNE
- Underway:
  - ν_e CCQE cross sections at 3GeV results in March
  - Analysis of the ν_e scattering with the medium energy
  - Ongoing work to reduce the flux uncertainty using the MIPP data and other techniques
  - Low ν method using the charged-current ν_μ scattering with low hadronic recoil energy

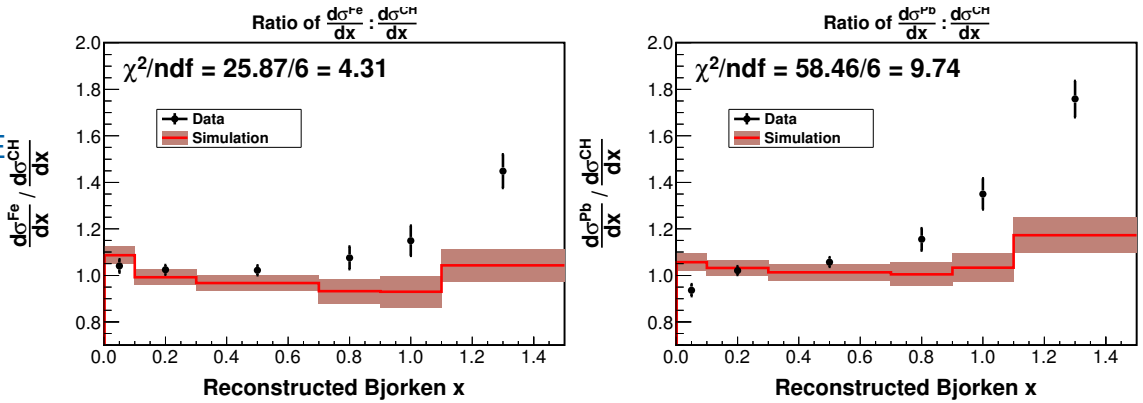


- Comparison of MINERvA data with JLab data to determine any differences between ν +A scattering and e-+A scattering
- MINERvA collaborators working on Event Generators (GENIE, NuWro) to improve the simulations

New Construction and Upgrades

- CAPTAIN-MINERvA proposal
  - High statistics measurements of neutrino interactions on argon in the medium energy range, unique results that will help to constrain models before LBNE

– Low energy ratios of inclusive cross section as a function of Bjorken x have disagreements with GENIE
– Ratios of the DIS cross section analysis in low energy is underway (results this year)



Phys. Rev. Lett. 112, 231801 (2014)

- Upgrades of the analyses from low energy to the medium energy
  - Medium energy provides excellent statistics for nuclear ratios: pion production, CCQE, and DIS
  - High statistics ready to be analyzed, a lot of opportunities for people wanting to join the Collaboration
- MINERvA needs antineutrino data to extract structure functions and measure partonic nuclear effects

Summary

- MINERvA will help to improve the nuclear model in event generators using data
- Results will directly contribute to reducing systematics associated with measuring CP violation and the mass hierarchy
- Several results will be released this year from low energy data
  - Electron neutrino CCQE cross section, muon neutrino CCQE double differential cross sections, Kaon cross section
- Starting to analyze the medium energy data (higher statistics, different energy spectrum)

Back Slides

CAPTAIN-MINERvA

- Proposal: Install the CAPTAIN detector in MINERvA to study neutrino-argon interactions in the medium energy NuMI beam
- Goals: Neutrino-argon cross sections, event reconstruction, and particle identification in the energy range relevant for ELBNF
  - NuMI's medium energy beam covers the 1st oscillation maximum for ELBNF at a baseline of 1300 km
- Availability of the CAPTAIN detector - earliest date CAPTAIN could be moved to Fermilab is 2016
- Data collection should begin by 2018 at the latest to ensure there will be enough participation from MINERvA collaborations for the project to be feasible

	Contained Events in CAPTAIN	Contained Events in CAPTAIN at pos 1 w/MINOS Match	Contained Events in CAPTAIN at pos 2 w/MINOS Match
CCQE-like	488,250	255,354	339,333
CC1$\pi^{\pm}$	191,250	59,478	88,930
CC1π^{0}	189,000	48,384	76,167

Table 1: Contained efficiency for CC events with a reconstructed muon using MINOS ND, assuming 6×10^{20} POT exposure.

Flux

- Flux estimate